1998

Analysis of vital subsystems of technical system maintenace

Milovan M. Ilić
MIN Holding Co. DD "Lokomotiva"
St. Šumadijska 1, 18000 Niš, Jugoslavija
E-mail: milovan@kalca.junis.ni.ac.yu

Dragan I. Temeljkovski, Pedja M. Milosavljević
Faculty of Mechanical Engineering University of Niš
St. Beogradska 14, 18000 Niš, Jugoslavija
E-mail: temelj@kalca.junis.ni.ac.yu
E-mail: pedja@kalca.junis.ni.ac.yu

Božidar S. Jovanović
Institute of Living and Working Environment Quality "1. Maj"
St. Trg oktobarske revolucije 1/I, 18000 Niš, Jugoslavija
E-mail: bozidar@ban.junis.ni.ac.yu

Abstract: The fundamentals of logistic support for the technical system maintenance contained in and described by the basic maintance subsystems, have been presented in this paper. The structure of the maintance system for major business was described throught the folloving subsystems: subsystem for the management of material and spare part supply process; subsystem for operation management; subsystem for technical diagnostics; subsystem for complaint processing; subsystem for reporting and data processing and subsystem for personnel planning.

This allows a multidisciplinary tretment of the technical systems throught their life cycle (begining with the preliminary research into the needs for supply or projecting, throught the process of production and installment, exploitation, to final wearing out) in order to manage the technical state and reliability of the technical subsystems, accompanied by clear decision documentation.

Key words: CIM; expert system; logistic; quality tools.

Introduction: The notion of maintenance comprises a series of procedures needed for preventing the incidence of the "failing" states, i.e. restoring the system from the "failing" state to the "operating" state, in the given time and environmental conditions. The process of technical system maintenance is characterized as an accidental process, since accidental changes of a number of magnitudes are inherent, inseparable from the process of maintenance. The final purpose of the maintenance process is to create bases reliable enough to, eventually, bring us to an improvement of all functions of maintenance, i.e., to an increase of technical system effect; a decrease of failures, by improving the level of technical system reliability; defining the bases for constructive-technological innovation, reconstruction (modification) of the system, work productivity increase in maintenance; a decrease in spare part stock, as well as an increase of the efficacy of enterprise management.

The development of industrial society and, more recently, information society, the consciousness of the importance and role of technical system maintenance has also developed although, for a long time, it had been regarded as isolated so that the models, i.e. maintenance concepts, did not keep pace with technical system development. Maintenance has evolved to the maintenance according to the state, terotechnology, integral logistic maintenance support, as well as maintenance in CIM (Computer Integrated Manufacturing) environment.

Maintenance should represent a multidisciplinary treatment of technical systems, throughout their life cycle, involving all procedures, methods and techniques which should be applied in order to keep a technical system, as long as possible, in proper (operating) state, so that during its expected lifetime it operates with the needed reliability, productivity and economy.

Fig. 1 represents the activities and mutual relationships during the exploitation cycle of the product. The block scheme, in fig. 2, shows the stages of technical system maintenance [1]. In the first stage, a technical description of the system is done, as well as its decomposition into subsystems and units. During the second stage, characteristic units to be maintained are sorted out by applying the Ishikawa method (Cause - Consequence Diagram) and Pareto (ABC) analysis, in order to detect the most influential units and to estimate the largest expenses. In the third stage, the methods of maintenance are determined, using the FMEA (Failure Mode and Effect Analysis) method of risk estimation. Following the choice and implementation of the specific maintenance method, in the fourth stage, the condition of equipment is analyzed.

Modern strategy of maintenance involves the techniques and procedures which provide documented decision-making, concerning the condition of equipment, tasks and measures to be undertaken, comprising a high level of scientific and multidisciplinary knowledge. The strategy can be technical and managing. Technical strategy is represented in fig. 2. Managing strategy gives an explanation of how to integrate the human factor, politics, equipment and reality in order to fulfill the contemporary business demands. Maintenance system is comprised of specific conceptual, organizational and technological solutions for managing the process of maintenance. The concept of maintenance process represents its most important features, since it considerably influences general quality of maintenance, depending on the principle on which decision-making about the procedure of maintenance is based. Concerning the concept, there are two basic solutions: preventive and corrective maintenance. These concepts can be linked into combined maintenance. In preventive maintenance, the needed procedures are performed before the appearance of failure, while in the corrective one, they are done after the appearance of failure.

Preventive maintenance according to the condition represents a modern conception of technological system maintenance, and a new approach to maintenance, based on performing proposed diagnostic examination (condition control), while the results, symptoms determine the application of appropriate maintenance procedures. Within the method of preventive maintenance, we do not distinguish only two extreme conditions,

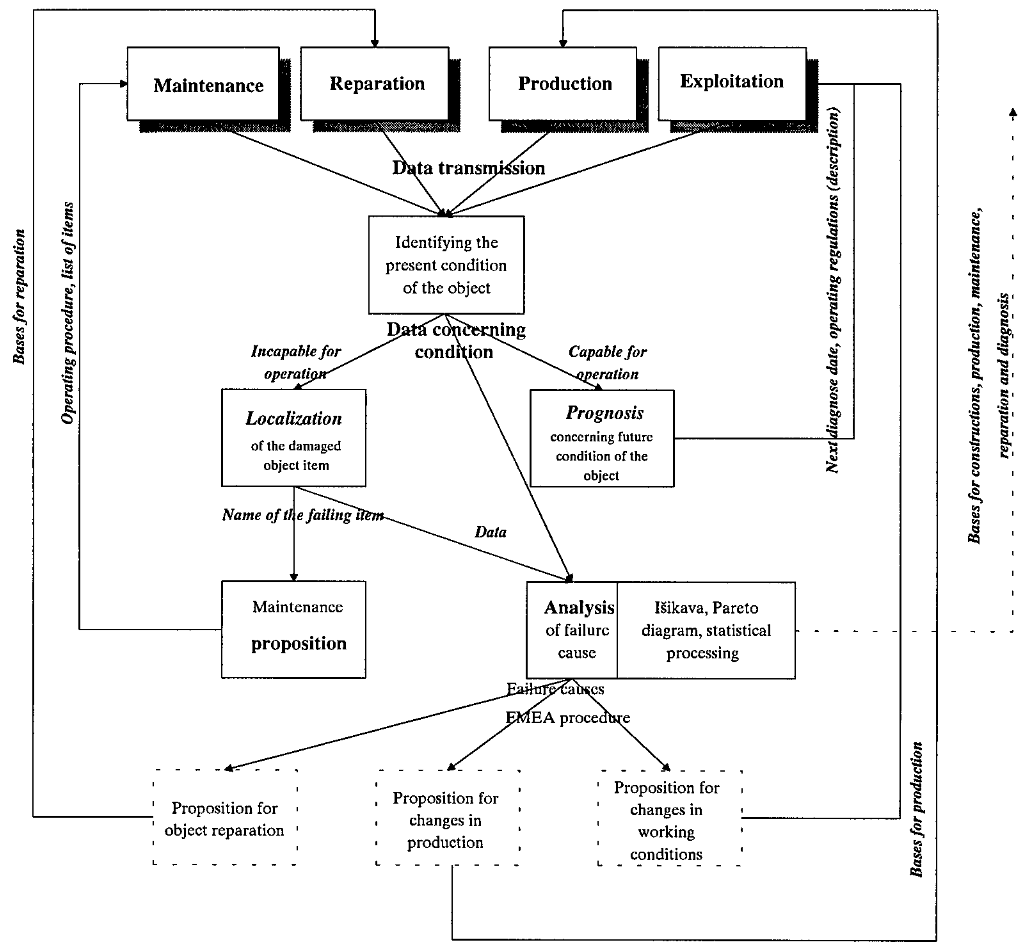

Figure 1. Activities during the use

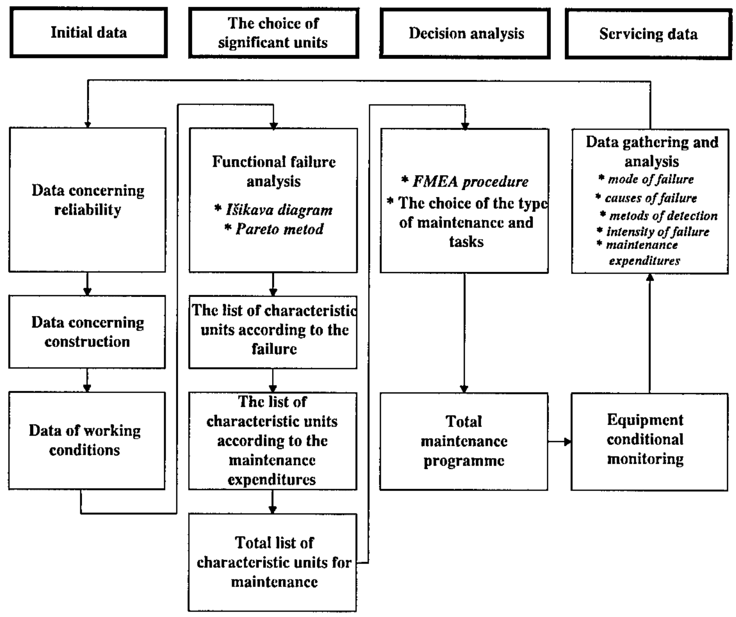

Figure 2. Basic stages and procedures of product maintenance

the state of failure and the state of operation, but also a large number of states between these two extremes. Thus, sudden failures, which are mostly caused by accumulated defects are minimized.

Instead of numerous experimental-pragmatic and/or scientific analytical conclusions about the system of maintenance, one conclusion is self-imposed:: maintenance comprises a factory (in factories).

The theory and practice of maintenance is greatly influenced by the tools, methods and techniques originating from the Japanese philosophy of production, which play a special role in increasing the level of productive systems (Toyota system - a productive-business system without making stocks; IT - Just in Time principle; Zero QC - Zero Quality Control or "Zero Defects"; TQC - Total Quality Control, etc.).

As shown in figures 1 and 2, the techniques of quality engineering comprise the essential engineering tools for a modern system of maintenance. These methods and techniques can be classified according to the area of usage in an enterprise (for product development, for an evaluation of quality provision, production management, etc.), or according to the steps they support in problem-solving (data gathering, problem identification, problem analysis, analysis of the relation between the cause and result, corrective activities, and result-effect verification). The mentioned tools can also be represented as Q7 - Seven Quality Tools (Q1 - Failure Summary List; Q2 - Histogram; Q3 - Control Charts; Q4 - Pareto Diagram; Q5 - Correlation Diagram; Q6 - Brainstorming; Q7 - Ishikawa Diagram); M7 - Seven Management Tools (M1 - Affinity Diagram; M2 - Relation Diagram; M3 - Tree Diagram; M4 - Matrix Diagram; M5 - Portfolio; M6 - Network Plan; M7 - Decision-making Plan); Information Quality Tools [2] (Internal Audit; Benchmarking; EDM /Engineering Data Management/; Statistical Methods; QFD /Quality Function Deployment/; FMEA).

Representation of vital maintenance subsystems. Having entered the sixth manufacturing ?poque, in 1985, referred to as an acronym, CIM - Computer Integrated Manufacturing, the conditions were created to develop a contemporary theory and practice of maintenance, maintenance in CIM environment. The CIM concept of enterprise management is, currently, the leading concept defining the organizational structure of an enterprise, directed towards the market. This concept also involves the JIT (Just in Time) concept, relying on the philosophy of the least possible capital stock keeping, i.e., the philosophy of manufacturing without any stocks.

By decomposing the basic modules of the CIM concept into lower levels, the role of maintenance can be shown within this concept, within the frame of production planning (PPS - Production Planning System) and management [3].

The basic objectives of maintenance planning are strictly dependent and, in great measure, identical with the basic objectives of production itself, and are usually solved as an integral part of the information system of an enterprise.

The basic functions of maintenance planning are: maintenance programme and planning; technological procedures of maintenance; time normative; material and spare part normative; planning for means of work on the maintenance jobs; operative and technical documentation processing; substitution plans for import of parts, materials, technology; planning for detection and removal of weak points; planning for modernization and reconstruction.

The structure of maintenance system for major business systems can be described through the following subsystems:

- subsystem for the management of material and spare part supply process
- subsystem for operation management
- subsystem for technical diagnostics
- subsystem for complaint processing
- subsystem for reporting and data processing and
- subsystem for personnel planning.

Subsystem for the management of material and spare part supply process. The process of material and spare part supply involves: needs analysis, supply or production (self-production or co-operant production), storage etc.. Spare parts necessary for technical system maintenance, i.e. the process of production, comprise an important element of logistic support of maintenance, and have a special role in the quality system of the management of maintenance process.

Part consumption for various technical systems and time intervals can be efficiently determined by Pareto (ABC) analysis of the significant minority and insignificant majority. By means of Pareto analysis application, it is determined that 10% of the parts comprise 70% of the total need for spare parts in railway vehicle reparation. This conclusion is very important because it indicates which spare parts should be held on stock.

The role of spare parts covered by supply in maintenance is significant, much greater than the role of spare parts self-produced in the workshops. This means that the quality of maintenance is also considerably influenced by external factors, introduced by the process of supply. That is why it is necessary to consider a number of target magnitudes and their effects (not only the prices). The supply process is characterized by the complexity increase of the parts to be supplied, where it is more and more usual to order the whole production systems, i.e. pre-constructed substructures, and less and less common to make orders of individual parts. This complexity, of course, increases the importance of deliverer's development of the product, and thus, his expenses, as well as the risk of development are also increased. The limited scope of the user's part production, as well as the increased demands for reliability and quality of the delivered products, make the necessity of the deliverer's involvement into the user's manufacturing trends even more pronounced. This can be made possible by minimizing the number of deliverers (as a rule, 1-3) per one part supplied, as well as by defining the deliveries by means of long-term, detailed contracts.

The common, contemporary practice of quality provision in supply, which is concentrated on examining the goods posterior to delivery, is not the expected future concept. The concept of quality provision includes all areas of quality provision, concerning the parts to be supplied.

The significant elements of the quality system also refer to handling, storage, packaging, conserving, as well as to delivery of materials and parts.

Subsystem for operation management. One of the most important functions of maintenance planning is also the management of activities, events, and procedures necessary for, or greatly influencing the maintenance process, including an application of specific methods and means.

The analysis of this element of logistic support should encompass the use of network plan for defining the "critical route" of the process, relation diagram for finding the needed relations, tree diagram for easier understanding of position of a part within a system, as well as QFD (Quality Function Deployment) quality house on the second, third and fourth levels. QFD Method usage allows decomposition of a product into certain systems, by making use of the second quality house, specification of production technology through the third quality house, while parameter definition is performed by making use of the fourth one. This new method is also efficiently applied in the maintenance domain.

This area is also concerned with the problem of refuse and additional production. Refuse and additional production make a special category of quality expenditure, internal loss expenditures. The theory and practice have shown that this category is the most important one among the quality expenses, and is often treated as a normal phenomenon in production. Enterprises are usually not aware of the real cost and causes of refuse. 10% of refuse means production more expensive for about 15%, since refuse means additional production. Increased percent of refuse or additional production can serve as a barometer of the state of overall production. It is very important to know that a systematic approach to this problem, can organize production without any refuse. The number of refuse created, additional production and satisfactory products in an operation can indicate the expenditures, and by monitoring the failures causing refuse or additional production, the real cause can easily be determined and prevented.

One of the basic initial functions of maintenance planning is also technological procedure designing, which involves technological procedure defining (primarily, the sequence), creating time normative, material and spare part normative, the choice of means of work and control (machines, tools, devices, auxiliary materials), etc. These activities are primarily based on experience and intuition of experts, and are, to great extent, supported by CAPP (Computer-Aided Process Planning) systems for automatization of technological procedure design. The current approach to the CAPP system development is based on non-algorithm programming and more frequent application of artificial intelligence method.

Subsystem for technical diagnostics. Contemporary maintenance is, primarily, a diagnostic process (condition checking), based on measurements, essential technical law application and specific empirical knowledge, so that an estimation of each system component condition can be done. Depending on the estimated condition, appropriate maintenance procedures (tuning, reparation, replacement, etc.) of aggregates and/or systems are performed. These activities are predominantly based on experience and intuition of the technologists, as well as their empirical knowledge and available information.

The crucial demands of diagnostic testing in exploitation are considerably different from the demands of production testing. Within a production process, the level of quality is defined by construction data, during the operation of exploitation the level of quality can vary, depending on the purpose of testing, different user's demands, different working environment, economy of maintenance, etc..

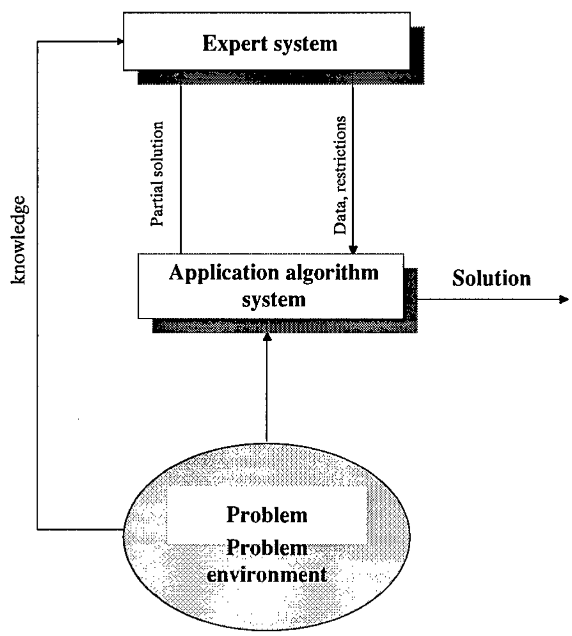

Figure 3. A software maintenance support model

The diagnostics involves: diagnostic testing for an estimation of the condition or failure on the module level; diagnostic testing for determining the cause of failures within a module; repaired module testing; complete testing in gross or general reparation.

The most effective procedure of condition diagnosing is based on an application of artificial intelligence, and primarily, on expert system application. Computers containing artificial intelligence allow a very flexible use of data, stored in them. If these data contain expert knowledge in some field, than the use of computers nearly equals consulting an expert. In this way, companies are provided with permanent possession of expert knowledge, instead of losing it when experts leave companies.

Subsystem for complaint processing. Complaints are often a current problem in production practice, but unfortunately, this problem is not approached in a systematic way, although it is well known that production can be organized in such a way, as to have an insignificantly small number of complaints, or no complaints (zero defect), where such an organization would cost less than the loss created by complaints. Complaints create an irreversible loss of time, material and energy, as well as new expenditures: classifications, analyses, additional production, refuse destruction, new product manufacturing, etc.. In such a way, companies lose even more than that: a reputation of successful enterprise, and finally, even worse, the customer.

Subsystem for reporting and data processing. Subsystem for reporting and data processing represents an integration of database and base of knowledge, thus providing on-line information about all relevant data concerning maintenance (fig. 3).

Data processing can be performed with respect to different objectives: short-term (close to the process) and long-term (beyond the operative plain, following the objectives which improve the process, e.g. weak point detection.

Data processing is a significant base for creating business regulation circuits, both internally within the plain, and on superimposed plains. Nowadays, it operates with powerful "tools", which allow adequate and accurate involvement of all business functions.

The primary objective of data processing is to contribute to quality proof demands. Data processing significantly contributes by preparing information about the product and the process of its creation, in order to provide and improve the quality of both the process and the product.

This subsystem comprises documentation management, which is an essential, unavoidable activity in every enterprise. Documentation management presupposes gross involvement of a large number of people, since the number of documents is gross, it is necessary to know where some document is kept, where it can be reached, etc..
Within the classical approach to documentation management of an enterprise, only a limited number of people is able to handle it, while it is not available to the majority of the employed.

Subsystem for personnel planning. Survival and development of an enterprise is based on a number of policies. The most important of them are: the personnel policy, developmental policy, business policy, quality policy, etc.. Personnel policy is determined, limited and, to some extent, directed by the objectives of an enterprise (developmental and business policy). By personnel policy the objectives to be achieved in some period of time are defined, as well as tasks, principles, and criteria in the domain of personnel function, together with the methods, procedures and means for achieving a goal in the domain of personnel function.

Personnel policy involves the following basic domains of activities or actions: personnel needs analysis, personnel provision (supply); distribution and promotion of personnel; personnel training; motivation and personnel safety.

The function of human resource management is basically limited to a tendency to give this resource a position similar to other business resources in the process of business management. As in the case of other production resources, it is not difficult to determine the productivity (compared to the appropriate objectives) and check the output quality, but it is more difficult, in this case, to introduce corrective measures.

A presentation of an information-expert system for the maintenance of railway tractive vehicles, created for the factory "Lokomotiva". The area of production of this factory is reparation and production of railway tractive vehicles (electric, diesel-electric, diesel-hydraulic locomotives and dollies), as well as production of railway tractive vehicles for special use.

Figure 4 shows the organizational scheme of an enterprise based on the CIM philosophy platform and global software business support. The organizational structure has 6 different modules of the CIM system: MIS - Management Information System; PPS - Production Planning System; CAD - Computer-Aided Design; CAP - Computer -Aided Planning; CAM - Computer-Aided Manufacturing and CAQ - Computer-Aided Quality. Module CIO - Computer Integrated Office, is also added the modules listed above, which integrates all office activities within an enterprise. The described organizational scheme is characterized by flat organization, without any hierarchy, thus providing direct information transmission to individual modules, as well as among the enterprise modules. CAM module should contain all examinations linked to production. This means that the tendency should be to greater self-control among the workers, abandoning the model of control performed by controllers.

The jobs on detecting defects - diagnostics, as well as the jobs concerning the technology of locomotive plant reparation have been supported by an expert system, which operates in integration with algorithm application systems. Such a configuration should allow an estimation of the solutions obtained by the algorithm systems, or their support by an expert system.

Conclusions. The following are the conclusions on the above said:

The proposed concept of maintenance is based on the CIM enterprise concept.

It is pointed out that information and people represent the crucial elements of possession of an enterprise. The more an enterprise accepts this essential concept, further cherishing and developing it, the more successful it will be.

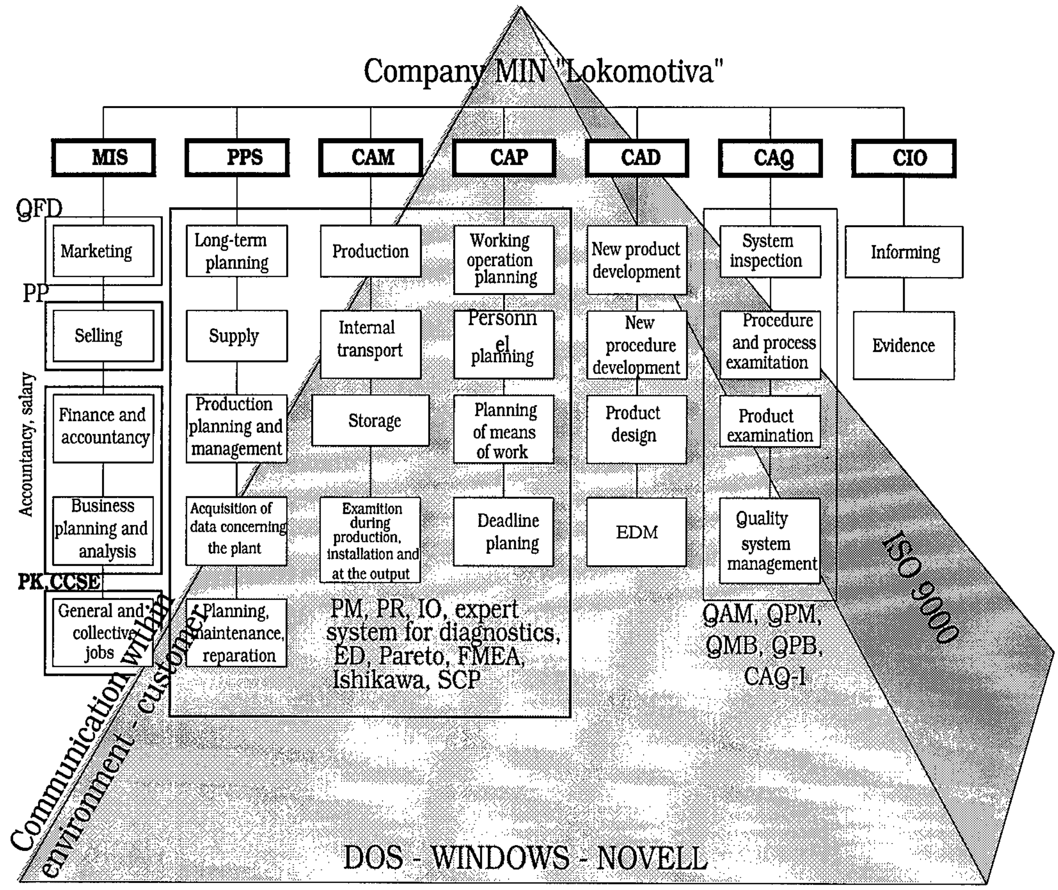

Figure 4 A model of organizational structure and software support to the reparation of railway tractive vehicles in the factory "Lokomotiva"

The basic process of contemporary maintenance is a diagnostic procedure (condition control), based primarily on measurements, although sorting out what should be measured, as well as result interpreting are also of importance. This paper suggests a solution to the problem, by an application of artificial intelligence, i.e., expert systems.

Computers enriched by artificial intelligence allow a very flexible use of data, stored in their memory. If these data contain expert knowledge from some area, then the use of computers nearly equals consulting an expert.

References

[1] Rac A.: Tribological aspects of production equipment maintenance, 26th International Conference of Productive Mechanical Engineering, Collection of Contributed Papers, 501-506, Podgorica - Budva, 1996.

[2] Stoiljković V.; Uzunović R.; Majstorović V. : Q-Tools, CIM Colege, Niš, 1996.

[3] Ilić M.: Expert system for railway tractive vehicle reparation, Faculty of Mechanical Engineering University of Niš, Niš, 1997.